W201910-1
Hiroshima Prefectural Hiroshima Kokutaiji Senior High School

# Evaluation method of road networks and Proposal for an ideal road network


# Research Motivation

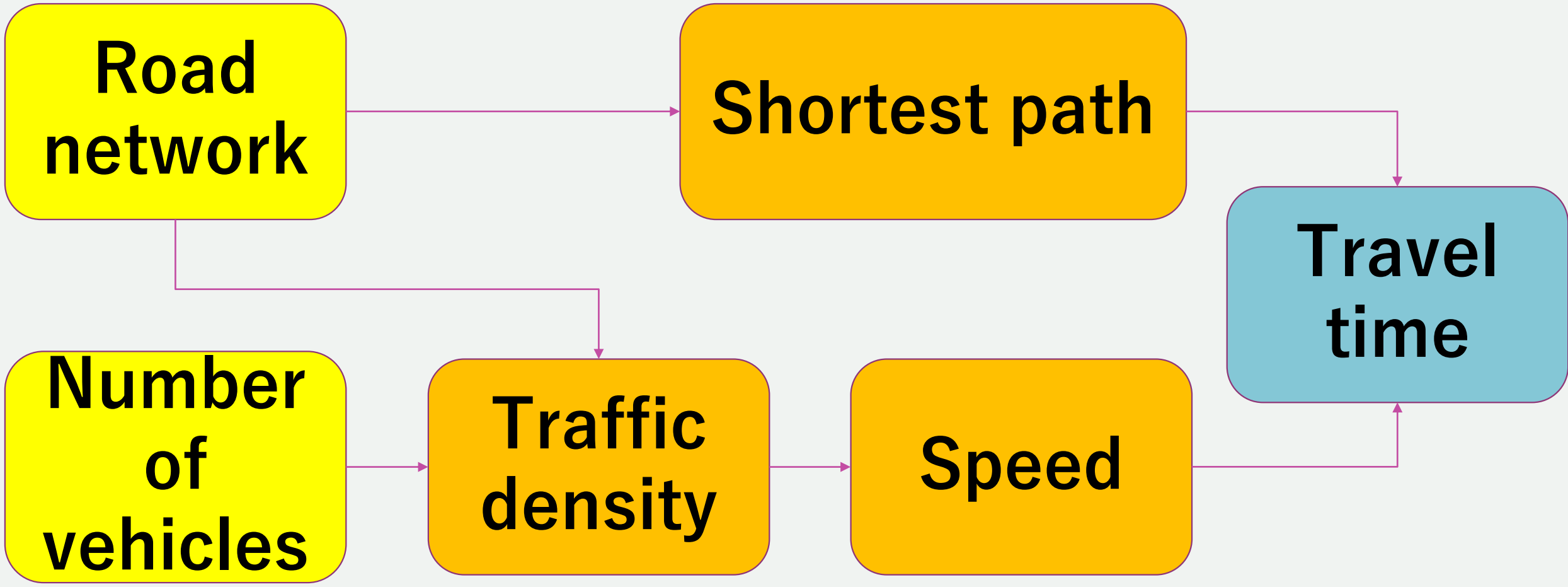
## Problems about traffic jam

- **30h** in losses per person per year
- **12,000,000,000,000 yen** in losses per year

## Solution for this

**Improve road networks**

# A method for evaluating road networks



# Define functions

- d(i,j)　:Distance [km]
- K(r)　:Density [vehicles/km]
- V(r)　:Speed [km/h]
- B(r)　:Betweenness
- T(i,j)　:Travel time [h]

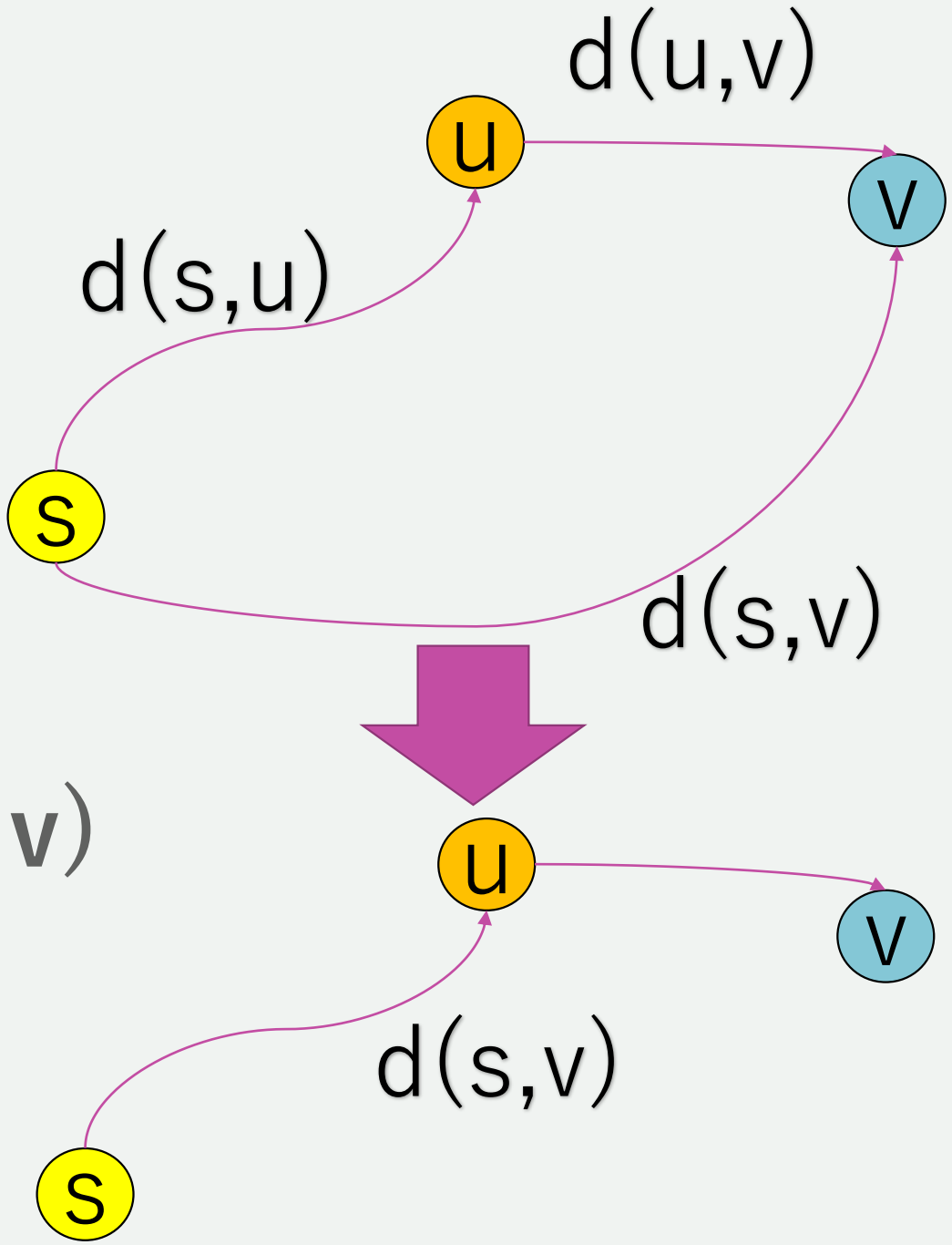
# Shortest path

Dijkstra's algorithm

Starting point…s

**If d(s,u)+d(u,v)<d(s,v)**

**d(s,v)=d(s,u)+d(u,v)**



# Speed V(r)

Relationship between density and speed

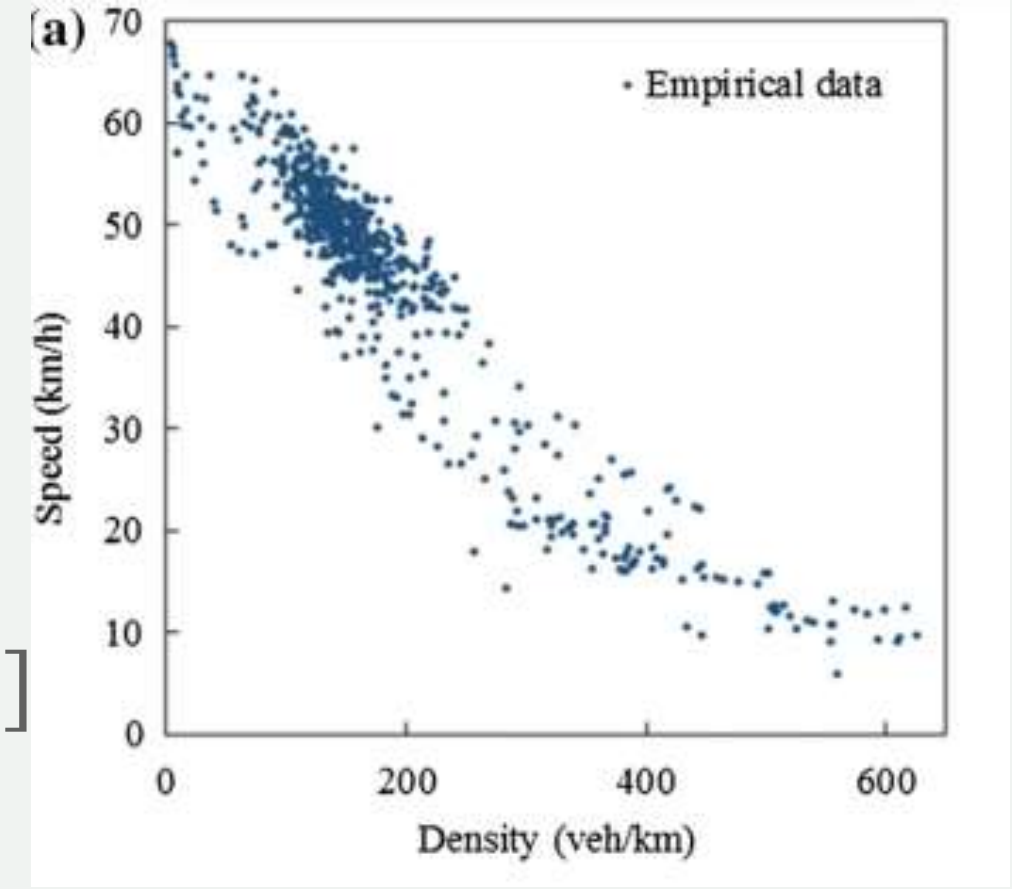
$$V(r)=Vf\ e^{-K(r)/Kf}$$

e=2.7182818286…

Vf…legal speed [km/h]

Kf…Traffic jam Density [veh/km]

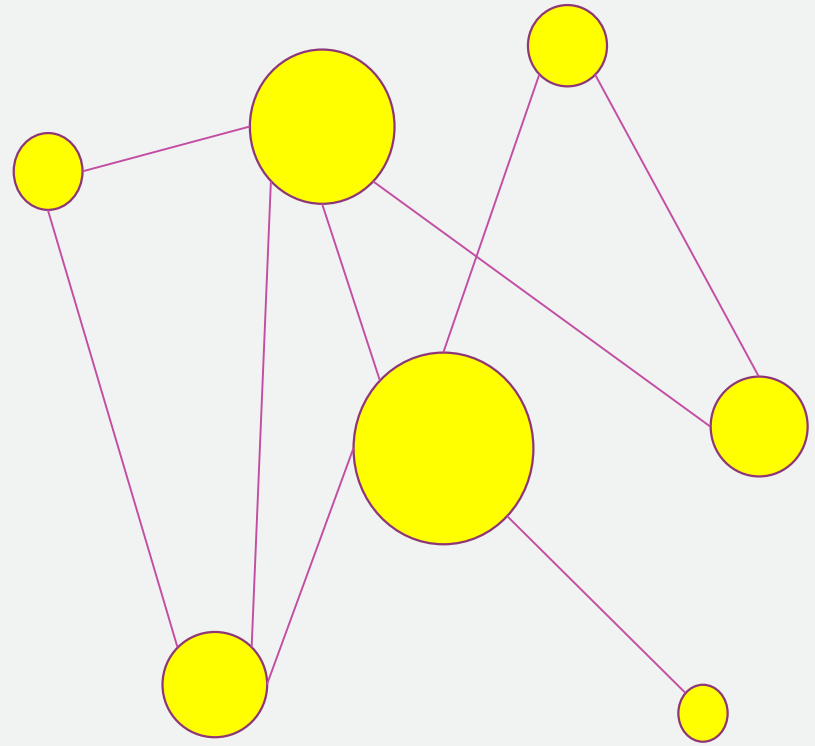
K(r)…Density [veh/km]



# Density K(r)　Betweenness B(r)

- $B(r)=\sum_{i\neq j}\frac{g(i,j|r)}{g(i,j)}$
- $K(r)\propto B(r)$

$$\mathbf{K(r)}=\frac{N\,B(r)}{\sum |r|B(r)}$$



N…Number of vehicles

|r|…The length of road “r”

## Travel time T(i,j)

$$T(i,j)=\sum_{r \in D}\frac{|r|}{V(r)}$$ D:Shortest path between i and j

**Sum of travel time** $=\sum_{i \neq j} T(i,j)$

This is an indicator for road networks

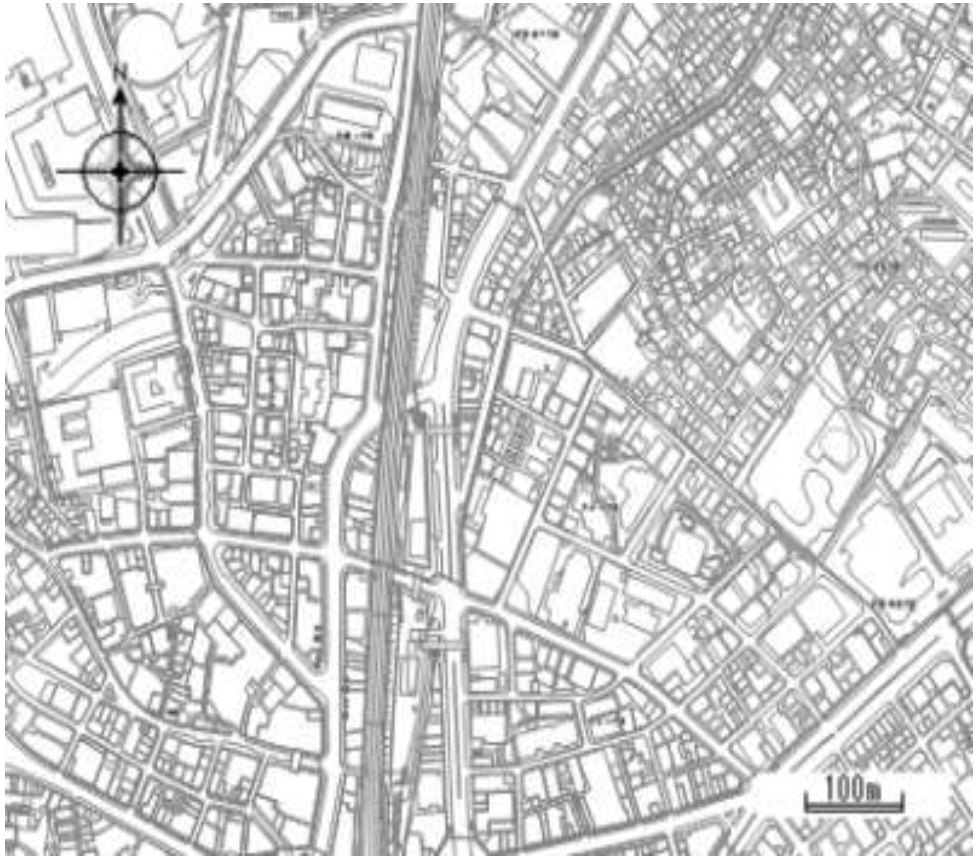
# Evaluate a real road network

| | Estimated | Measured |
|---|---|---|
| Speed [km/h] | 45.7 | 19.9 |
| Sum of travel time [h] | 713 | 1637 |

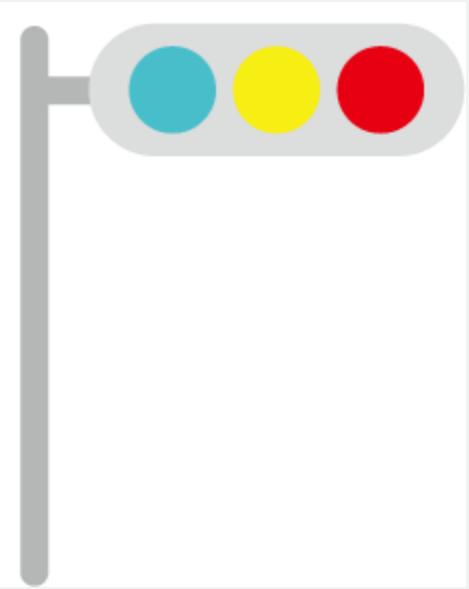
# Shibuya

Node:225

N=1262



# Why was the difference so large?



Main reason…Traffic lights

$$\text{Wasted time} = \frac{T - T'}{\sum Bt(i)} = 31.9\,[\text{s/traffic light}]$$

Reasonable value!

$$\text{Sum of travel time} = \sum_{i \neq j} T(i,j) + \frac{31.9}{3600} \sum Bt(i)$$

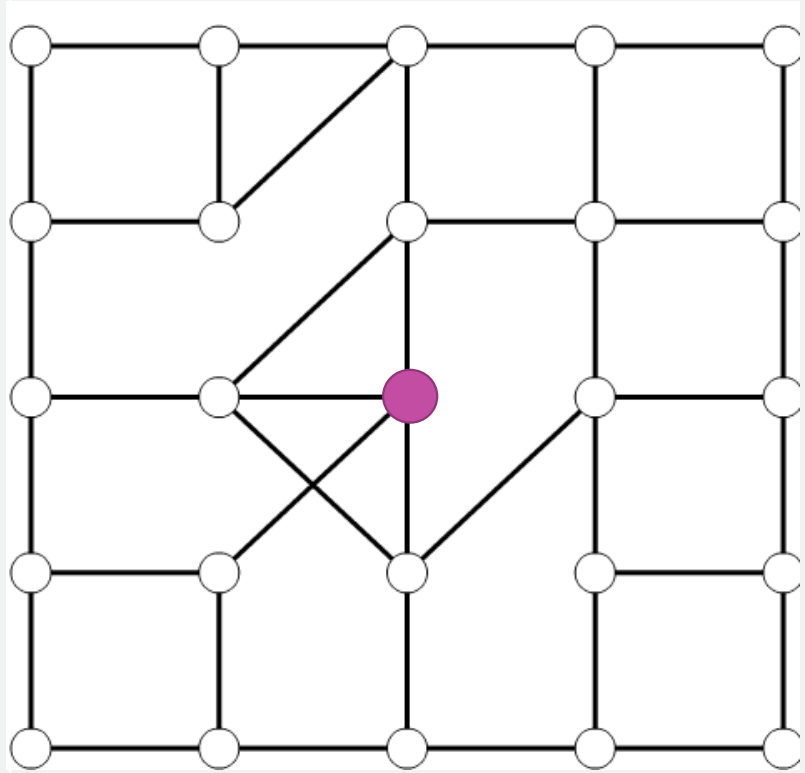
# Proposal of ideal road network

## Requirements

1.The degree of the vertex is between 2 and 4.

2.The length of the road is 1 or $\sqrt{2}$ .

3.Traffic lights are at crowded points.



## Data

Node:15×15

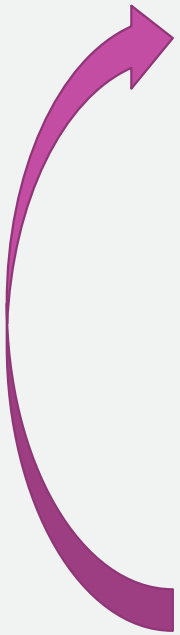
Number of vehicles=1262[veh]

1=0.067[km]

Number of traffic light=29

Same as Shibuya

# Hill climbing method



1. Make some changes to the road network

2. If “Sum of travel time” becomes smaller, adopt the change.

3. Make changes randomly and Return to 1. again.

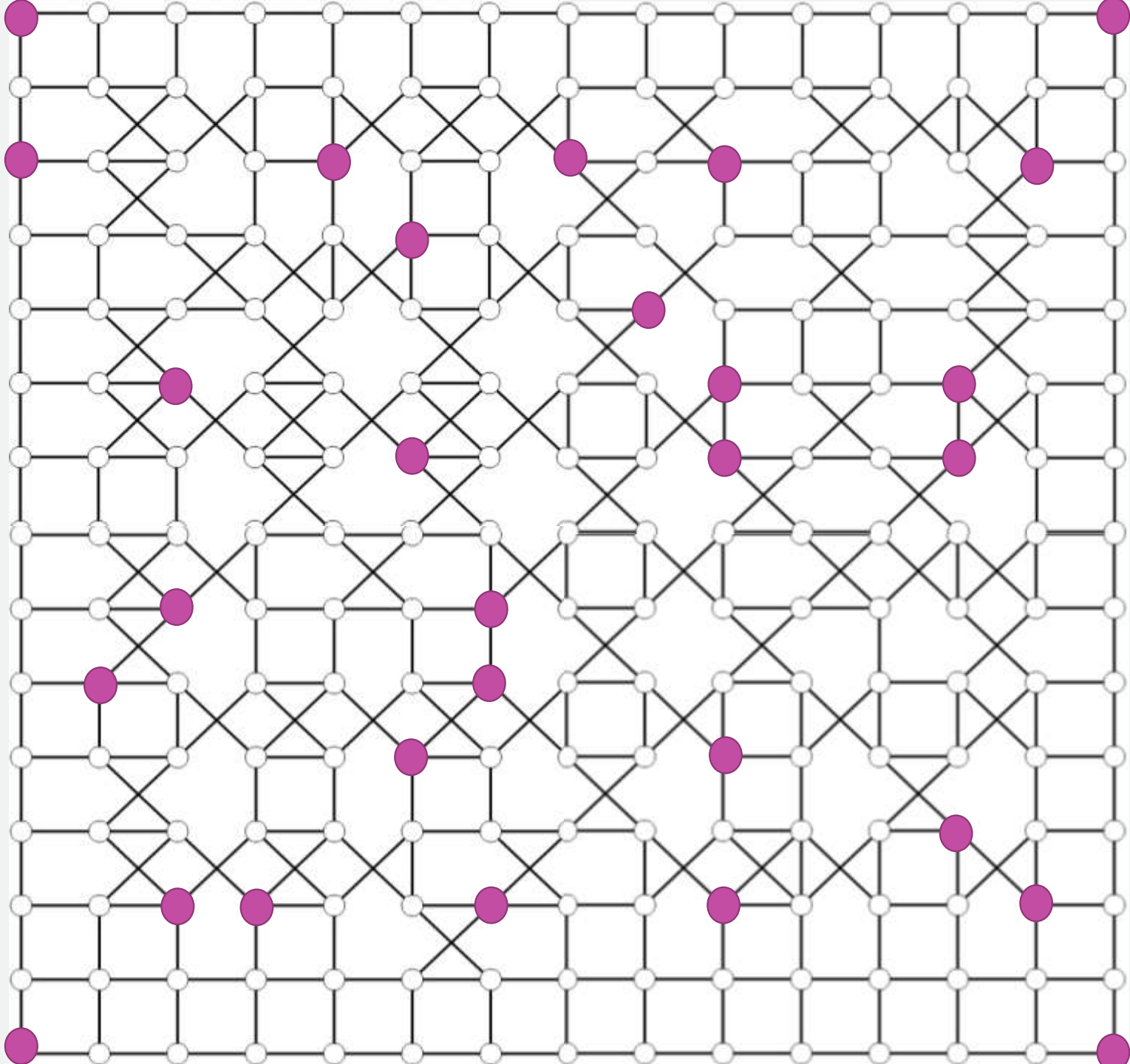
4. After 100 times of 3., stop it.

# Result

**38.6%** reduction

| | Shibuya | Ideal |
|---|---|---|
| Speed [km/h] | 19.9 | 31.0 |
| Sum of travel time [h] | 1637 | 1005 |

# The ideal road network



Traffic light

# Conclusion

Average driving time …**1.3**[**h**/**day**]

In the ideal road network..

$1.3 \times 0.386 = 0.509$[h/day]$=186$[h/year]

can be saved!

→ **Save Time & Resources**

**Reduce CO2**

# Reference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